Effect of Postprandial Posture on Digestion and Absorption of Dietary Carbohydrate

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Abstract The effect of postprandial body posture on digestion and absorption of dietary carbohydrate were examined through breath hydrogen test on 6 female subjects. During the experiment, the participants either sat on a chair or lay on their backs for the first 4 hr (from 08:00 to 12:00) after eating the test breakfast meal. They then remained sedentary on a sofa for 6 hr (12:00 to 18:00). Participants’ end alveolar breath samples were collected for 10 hr (every 15 min from 08:00 to 12:30, and then every 30 min until 18:00). The experiment was conducted on two consecutive days using a randomized, crossover study design. The results demonstrated that in the supine position orocecal transit time of the test meal was significantly slower than in the sitting position (260 ± 21 min and 238 ± 20 min, respectively, p<0.01). In addition, afternoon breath hydrogen excretion due to a partial malabsorption of dietary carbohydrate and its fermentation in the colon was significantly larger in the sitting position (144.0 ± 24.1 ppm·hr) than in the supine position (110.0 ± 26.1 ppm·hr, p<0.05). These results support the hypothesis that there was a marked effect of postprandial body posture on the function of the digestive system. The present findings suggest that the supine position is preferable to the sitting position after taking ordinary meals. Therefore, we need experimental evidence to help us to make informed decisions about the most suitable postprandial body posture for the elderly people in order to improve their quality of life.

Keywords: breath hydrogen test, postprandial posture, digestion and absorption, dietary carbohydrate

Introduction

In our daily life, most of us pay no attention to the body posture during and after meals. However, postprandial posture is recognized as a problem in the field of nursing, especially in the care of elderly people in hospitals or nursing homes. There is also evidence that postprandial appetite may be influenced by body posture, an effect that may be mediated by changes in intragastric meal distribution or the rate of gastric emptying (Horowitz et al., 1993). Moreover, the rate of gastric emptying affects the efficiency of digestion and absorption of nutrients in the gastrointestinal tract (Moukarzel and Sabri, 2000). These effects of postprandial body posture on the digestive system may be pronounced in elderly people because of their declining digestive, absorptive and metabolic activities (Sone, 1995). There has also been some confusion in the care of elderly people confined to bed, whether they should keep sitting on the bed or should change their body posture to the supine position after taking ordinary meals. Therefore, we need experimental evidence to help us to make informed decisions about the most suitable postprandial body posture for the elderly people in order to improve their quality of life.

Among the papers concerning the effect of postprandial body posture on the gastrointestinal tract, several papers deal with postural effects on the gastric function. However, there is no agreement among their experimental results. Asada et al. (1989) and Moore et al. (1988) reported an association between postprandial sitting position and the faster gastric emptying of solid meals, but Doran et al. (1998) showed that the major effect of meal volume had a greater effect on gastric emptying than postprandial posture.

In contrast, there are few papers dealing with the postural effect on the digestion and absorption of dietary nutrients. This is probably because of the lack of development of simple and noninvasive method applicable for the examination of digestion and absorption of food in human subjects. During the course of our recent investigation concerning the effect of our
daily environmental factors, such as skin pressure and daily illumination (Sone et al., 2000, Lee et al., 2001, respectively), we found that breath hydrogen test (Levitt and Donaldson, 1970; Bond and Levitt, 1975) is a simple, useful and noninvasive method for the assessment of the gastrointestinal functions including orocecal transit time and malabsorption of dietary carbohydrate (here, we define it as those digested by endogenous enzymes, such as sugars and starches).

In this paper, we examined the orocecal transit time and digestive efficiency of dietary carbohydrate in a morning meal by means of breath hydrogen test in two body postures (sitting position and supine position), and discuss which postprandial body posture is preferable from the viewpoint of digestion and absorption of dietary carbohydrate.

Subjects and Methods

Subjects
Six healthy female students (age 19 years, body weight 48.7 ± 5.8 kg, height 157.2 ± 4.4 cm, mean ± SD), who are not suffering constipation, took part in this experiment. The experiment was conducted on two consecutive days during either a participant’s follicular or luteal phase of her menstrual cycle, excluding menses. All participants were non-smokers and free of conditions that would alter the colonic flora, such as antibiotic therapy, for at least 2 months prior to the commencement of experiment (Gilat et al., 1978).

Each participant gave written informed consent for this experiment.

Experimental procedure
Figure 1 summarizes the experimental procedure. The
The experiment was conducted for 3 days. The first day was the control phase for measurement, the second and third days were the measurement phases of "sitting" and "lying". These two phases were conducted on consecutive days and the order of the two phases was randomized for each subject.

On the day prior to the experiment, we instructed each of the participants to eat the same amount of given diet which was served at 19:00 (dinner) and then go to bed at 23:30. To avoid the effects of drinking coffee and tea on the gastrointestinal function via their caffeine content, the participants were only allowed to drink water during the experiment. The participants entered the experimental room (illuminated at 2,000 lx, roughly controlled at 20°C and 35%) at 07:30 the next day and changed from their own clothing into loose-fitting experimental garments that are free from skin pressure (Sone et al., 2000).

The participants took the test meal at 08:00 sitting on a chair and their breath sample were collected every 15 min from 08:00 (beginning just before taking the test meal) until 12:00, followed by every 30 min sampling until 18:00. The test meal was prepared to have homogeneous consistency so as not to readily separate into solid and liquid phases (Read et al., 1980). Lunch, a snack and dinner were ordinary meals and were served at 13:00, 16:00 and 19:00, respectively. The foods and composition of the meals served during the experiment is summarized in Table 1. For each subject, the same time schedule was repeated on the third day with different postprandial posture.

In the “sitting” experiment, the participants sat on a chair for 4 hr (from 08:00 to 12:00) then took a sedentary posture on a sofa for the additional 6 hr. In “supine (lying on their back)” experiment, the participants lay on a bed for 4 hr just after taking a test breakfast meal (from ca. 08:20 to 12:00) and then remained sedentarily for 6 hr as in the “sitting” experiment. The participants were allowed to listen to music and/or read magazines, but they were not permitted to take a nap or to lie down. This experiment was performed in November and December 2000.

**Breath hydrogen analysis**

We collected participants' end alveolar breath samples for 10 hr (every 15 min from 08:00 to 12:30, and then every 30 min until 18:00) using the special breath-collection bag purchased from TERAMECS (Kyoto, Japan).

The breath hydrogen concentration in the collection bag was measured by gas chromatography (MicroLyzer model 12i, Quinton Instruments, Milwaukee, WI, USA) and expressed as parts per million (ppm). We defined the orocecal transit time as the time from the test meal ingestion to the time when the breath hydrogen is increased to more than 5 ppm over baseline levels, which were sustained for at least two consecutive intervals (Hirakawa et al., 1988). The area under the hydrogen concentration vs time curve, which was calculated from the initial sustained rise for hydrogen to 18:00, was used to represent hydrogen excretion due to the fermentation of undigested and unabsorbed dietary carbohydrate residues from the small intestine by microflora in the colon. Hydrogen excretion was measured in ppm·hr.

**Statistical analysis**

All results are expressed as the mean values ± SEM, or where indicated, as the mean values ± SD. The means of orocecal transit time and breath hydrogen excretion between the two groups were compared using the paired Student t-test. A p-value<0.05 was considered to be significant.

**Results**

Figure 2 shows the serial exhaled breath hydrogen concentration data (mean ± SEM) from six subjects with sitting posture (closed circle) and supine position (open
circle). This figure shows that both curves have similar breath hydrogen exhalation profiles with 5 distinct phases; (1) increase in H₂ levels during the first hour after the test meal, (2) a fall to low baseline levels, (3) a slow increase in H₂ production from 11:00 to 11:30, followed by (4) a sharp elevation of hydrogen concentration, and finally (5) continuous high breath hydrogen levels. However, there are two clear differences between the two curves. One is the time when the breath hydrogen level starts to increase (sitting at 11:00, supine at 11:30); the breath hydrogen level starts to increase faster in the sitting position than in supine position. This difference reflects shorter orocecal transit time of the test meal in the sitting position than that in the supine. Figure 3 shows that the difference in the average orocecal transit times for both postures were statistically significant ($p<0.01$). The second is the breath hydrogen level after 13:30 (phase 5); the breath hydrogen levels in sitting position are clearly higher than those in supine one. In this experiment, all the six subjects exhaled more breath hydrogen in sitting posture than in supine. Figure 4 shows the average area under the curves, indicating that pronounced excretion of breath hydrogen in “sitting” position compared with that in the “supine” position was significant ($p<0.05$). These results indicate that the more unabsorbed carbohydrates moved into the colon in sitting position than in supine.

**Discussion**

In the present study, we obtained two clear-cut results: (1) the orocecal transit time in the postprandial supine position is significantly longer than that in the sitting position (Fig. 3); and (2) the excretion of breath hydrogen...
was significantly less in the supine position than in the sitting (Fig. 4). The test meal thus traveled through the upper gastrointestinal tract more slowly and less undigested and unabsorbed carbohydrate moved into the colon in the postprandial supine position than in the sitting posture.

The breath hydrogen test is used to estimate the orocecal transit time of the meal, which is the time from the ingestion of food to the passage of the ileal chyme into the cecum. We exclude the effect of the postprandial postures on the rate of gastric emptying and on the transit time of the chyme in the small intestine. Our results suggest that there was no effect of postprandial posture on transit of digests through the small intestine (Fig. 2). We repeated the same experiment, using lactulose-contained milk as a breakfast test meal in place of minestrone, where we noticed that there is no difference in the small intestinal transit time between the two postprandial postures (Hirota et al., unpublished results).

Taking into account that the postprandial posture has no effect on the small intestinal transit time of the test meal as described briefly in the proceeding paragraph, we can suspect that the rate of gastric emptying in the postprandial supine position was slower than in the sitting one. Concerning the regulation of gastric motility and emptying, it is generally accepted that the rate at which the stomach empties into the duodenum depends on the ratio of component nutrients of food ingested and the osmotic pressure of the material entering the duodenum (Ganong, 1999). In this experiment, all subjects' meals ingested were controlled and have the same nutrients composition throughout the experimental period. We can thus ignore these factors. There are several studies of the relationship between the body posture and the rate of gastric emptying. Moore et al. (1988) and Asada et al. (1989) used radioactive or sulfamethizole labeled solid meals as test meals and detected the moving of food with a scintillation camera or through determination of sulfamethizole blood concentration, respectively. Both studies found that gastric emptying in the lying position was significantly slower compared to the sitting position kept either for 90 min or 120 min. Our present result supports their findings. The mechanism underlying the delay in emptying is not yet clear, but the following factors are thought to be involved: the antigravitational effect of recumbency, meal pooling, and reduced antral distensibility (Moore et al., 1988).

Regarding the relationship between the postprandial posture and digestion and absorption of dietary carbohydrate, this experiment provided us with a very interesting result. The efficiency of the carbohydrate absorption is better in the supine position than in the sitting, indicating that the slower the gastric emptying, the better the absorption of dietary carbohydrate is. There have been few studies dealing with the postural effect on the digestion and absorption of dietary carbohydrates. Recently, Moukarzel and Sabri (2000) reported an interesting finding in their study of 23-month- to 14-year-old children using white grape juice and pear juice (pear juice has higher fructose to glucose ratio and higher sorbitol content than white grape juice). They reported that white grape juice was associated with lower gastric myoelectric activities, slower gastric emptying, more absorption of dietary carbohydrate, and less breath hydrogen production than pear juice. Their finding is coincident with our present result; the slower the gastric emptying is, the better absorption of dietary carbohydrate is. Based on these results, we can speculate that if the rate of gastric delivery of the chyme to the small bowel is fast, the absorption of dietary carbohydrate by the small bowel may be decreased because of shorter contact time with the brush border membrane across which the nutrients are absorbed. In addition, we should also consider that the effect of the autonomic nervous control on the gastrointestinal function which may contribute to the better absorption of dietary carbohydrate in the small intestine when the subjects take supine position after meal. Miki et al. found that the relaxed posture is associated with the decrease in the sympathetic nerve activity during normal daily activity of Wister rats (Miki et al., Nara Women’s University, personal communication). Although this result is hard to accept for human beings directly, it is likely that the relaxed postprandial supine position results in a decrease of sympathetic nerve activity previously elevated by the
action of eating and the resulting prevalence of parasympathetic nerve system. Thus, the postprandial supine position affects the small intestinal functions to increase the absorption of dietary carbohydrate. More evidence is needed to test this hypothesis.

Finally, we would like to discuss the practical application of our research, i.e., the most suitable postprandial posture for the elderly persons in order to improve their quality of life. Our results indicate that the postprandial supine position is preferable to the sitting position from the viewpoint of the absorption of dietary carbohydrates. In contrast, Asada et al. (1989) proposed that a postprandial sitting position is desirable for gastric digestion and emptying of solid food, especially in the old aged persons based on their experimental results. Nowadays, Asada’s proposal seemed to be accepted as a standard concept in the field of nursing. In addition to the prompt gastric emptying in the sitting position, the 2 hr postprandial sitting position is preferable to the supine one because of the prevention of respiratory infection in among the elderly bed-bound nursing home patients (Meguro et al., 1992). Meyers and Herb et al. (1982) also suggest that the postprandial lying position could not be accepted in nursing because of its undesirable effect on the gastroesophageal reflex, which leads to the reflux of acid gastric contents into the esophagus. However, among the normal subjects, Nakagawa et al. (1998) suggests that no effects of the postprandial positions on the esophageal acid exposure are found. The findings of Nakagawa et al. and the results of this study suggest that the most desirable postprandial position for the elderly people will depend on their general state of health.

In summary, the orocecal transit time in the postprandial supine position is significantly longer than that in the sitting position and the excretion of breath hydrogen was significantly less in the supine position than in the sitting.

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